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REVERSE LOGISTICS OF POST-CONSUMER WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT IN THE CITY OF TERESINA

Franciwellington Barros do Nascimento
franciwellingtonep@gmail.com
Federal University of Piauí – UFPI, Teresina, Piauí, Brazil

Yasmin Batista Ramos da Silva
yasmimmbrs@gmail.com
Federal University of Piauí – UFPI, Teresina, Piauí, Brazil

Leandra Silvestre da Silva Lima
leandra.silvestree@gmail.com
Federal University of Piauí – UFPI, Teresina, Piauí, Brazil

Maria do Socorro Ferreira dos Santos
socorroferreira@ufpi.edu.br
Federal University of Piauí – UFPI, Teresina, Piauí, Brazil

ABSTRACT

With globalization and the accelerated advancement of technologies, it is becoming increasingly easy to acquire electrical and electronic devices, resulting in obsolete products that are, consequently, discarded by their owners. The disposal of electrical and electronic waste has become an increasingly serious socio-environmental problem, since they contain heavy metals that are highly harmful to the environment and to human health. The research sought to investigate the reverse logistics of waste electrical and electronic equipment in the city of Teresina, Piauí, based on Law 12,305/2010. The research is exploratory, non-probabilistic, qualitative and quantitative. The necessary data were collected from January to July 2017, through a field survey, by means of the application of 60 closed questions, including seven objective questions, with the population, whose sample was chosen in a random manner, considering different neighborhoods of the municipality. Interviews were also carried out with companies that receive this type of waste and then with the companies specialized in the reverse logistics process of waste of electrical and electronic equipment (WEEE), one located in the city of São Paulo, SP and the other in the city of Recife, PE. The results showed that the population shows an interest in the environmentally appropriate disposal of this type of waste, but most of them continue to do so inadequately. The local companies carry out the proper collection and disposal, and then send the material to the company specialized in the manufacture of waste electrical and electronic equipment in Recife, PE. The city of Teresina advances in the management of WEEE; however, it still lacks the disclosure and participation of companies and public agencies so that the population may be becoming aware of and being responsible for the process of environmentally appropriate disposal of this type of waste.

Keywords: Reverse logistic; Waste; Electrical Equipment and Supplies.

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1. INTRODUCTION

Environmental management in the electro-electronics industry is relatively recent and the focus of environmental pressures is no longer the environmental management of production, but rather the environmental management of the product, which considers the durability of the product, the possibility of recycling, the type of raw material used, the ease of dismantling and reusing, the type of packaging and its recycling process, aiming at a lower environmental impact after consumption (Kobal *et al.,* 2014).

Brazil has an increasing rate of generation of electronic waste, but currently there are few adequate management systems in operation, with the largest share of waste electrical and electronic equipment (WEEE) going to landfills or entering informal chains (Sousa *et al.,* 2016). In August 2010, the National Solid Waste Policy (PNRS, acronym in Portuguese) was instituted, and it establishes principles, objectives, instruments, as well as guidelines on integrated management and solid waste management. Among the principles, the most discussed aspects of society have been shared responsibility and the recognition of solid waste reusable and recyclable as an economic good and of social value, generator of work and income and promoter of citizenship (Brasil, 2010). The law states that all actors involved in the generation and management of solid waste, be they producers, importers, wholesalers, retailers, final consumers and public authorities have shared responsibility for waste management (Domingues *et al.,* 2016).

The present research aimed to investigate the reverse logistics of post-consumption WEEE in the region of Teresina, Piauí, by means of the survey of characteristics of the behavior of the local population, mapping and analysis of collection points in the city, and diagnosis of the processing of the residues carried out by companies at the end of the production chain.

2. THEORETICAL REFERENCE

Waste electrical and electronic equipment

The inadequate disposal of WEEE is a major concern in the field of reverse logistics in Brazil and in the world; thus, Bizzo *et al.* (2014) mentioned that the proper disposal of this waste is currently a concern of environmental researchers and managers not only because of the large volume of waste generated but also because of the heavy metals and toxic substances it contains.

Electronic waste is one of the fastest growing pollution problems in the world given the presence of a variety of toxic substances that can contaminate the environment and threaten human health if the disposal protocols are not meticulously managed (Kiddee *et al.*, 2013).

According to Schroeder *et al.* (2015), WEEE contains valuable and differentiated materials from other wastes, but due to their composition they can cause harm to human health, since the direct or indirect contact with these metals causes damage to the biological activity, and may even lead to the death of those who are in contact, depending on the substance and amount to which the individual is exposed, as specified in Table 1.

Chart 1 - Heavy metals present in waste electrical and electronic equipment and major damage to human health

Element	Main damage to human health
Aluminum	Some research suggests that there is a relationship between chronic aluminum contamination as one of the environmental factors and the occurrence of Alzheimer's disease.
Barium	Causes effects on the heart, constriction of blood vessels, elevation of blood pressure and effects on the central nervous system.
Cadmium	It accumulates in the kidneys, liver, lungs, pancreas, testicles and heart; has a half-life of 30 years in the kidneys; cases of chronic intoxication may lead to bone decalcification, renal damage, pulmonary emphysema, in addition to teratogenic (fetal deformation) and carcinogenic (cancer) effects.
Lead	It accumulates in the hair, bones, brain and kidneys; in few concentrations causes anemia and headaches. It exerts toxic action on the nervous system, on the biosynthesis of blood, liver and renal system; it is a cumulative poison of chronic intoxication that causes gastrointestinal, hematological and neuromuscular changes, which can lead to death.
Copper	Intoxications with liver damage.
Chrome	It gets stored in the lungs, skin, muscles and adipose tissue, can cause anemia, liver and kidney changes, besides lung cancer.
Mercury	It easily traverses the cell membranes and is readily absorbed by the lungs. It has properties of precipitation of proteins (modifies the configurations of the proteins), and is sufficiently serious to cause a circulatory collapse in the patient, leading to death.
Nickel	Carcinogenic (acts directly on the genetic mutation).
Silver	10g in the form of Silver Nitrate are lethal to man.

Source: Adapted from ABDI, 2013

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Reverse logistics: channel for the management of waste electrical and electronic equipment

Manufacturers and consumers have been pressured by environmental regulations and sensitization to target environmentally responsible products through reverse logistics, as it is part of an extensive supply chain and return management process, and is also included in the supply chain, so that the allocation of management can analyze and consider the obstacles vital to the survival of industries in the future (Senthil et Sridharan, 2014).

The flowchart of Figure 1 represents the reverse logistics systems, indicating the ways of return of the materials to the industries and subsequent availability to the consumer market, between supplier, manufacturing companies, and consumers.

Figure 1 shows, in a simplified way, the flows in the reverse logistics, allowing a more didactic understanding of how this process occurs and a mapping of ideas with respect to the context of waste return as a product form.

Demajorovic *et al.* (2016) consider that the flow from traditional logistics follows a sequence in which the new product is produced, stored, dispatched, distributed, and consumed; while the flow from reverse logistics is directly related to the return of products and packaging so that they can be processed and returned to the production process as a secondary raw material in the production of new products.

Post-consumer reverse logistics is at the heart of a company's disposal of a good, and its time of disposal can vary between days and years. In the words of Resende (2004), the different forms of processing and commercialization, from their collection until the integration to the productive cycle as secondary raw material, are called reverse distribution channels of post-consumption.

Post-consumer reverse logistics can also be understood as part of the reverse logistics of companies seeking the recovery of recyclable products, which can be sent to traditional final destinations, such as landfills and incineration, or can return to the productive cycle (Souza *et al.,* 2012). The authors add that this process represents an alternative of equation of the paths covered by the constituent materials after the end of the useful life of their products.

It is possible to observe a growth of the post-consumer reverse logistics while there is an increase in the launching of new products with the use of other sources from materials constituting recovered solid waste (Ferreira, 2012). In this context, the author considers the advent of the reverse cycle to be of utmost importance, because it is common to find solid waste that has conditions of reuse and, even so, they are discarded incorrectly, wasting their added value.

According to data from the Brazilian Industrial Development Agency (ABDI, 2013, acronym in Portuguese), WEEE collection is usually done in conjunction with other types of waste by recyclable waste pickers, and some people often say that they do not know how to properly dispose of these types of waste. This fact is considered the only way to correct the support to society, with collection sites for WEEE; however, it is an insufficient strategy, as there is a need to train and provide the appropriate protection equipment to

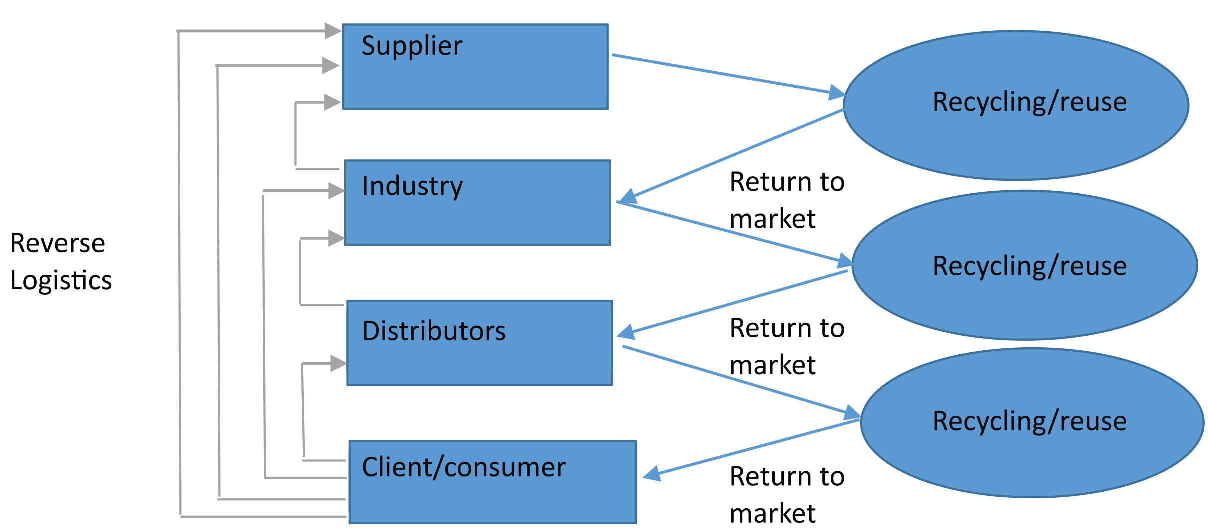

Figure 1. Simplified reverse logistics scheme
Source: IPEA (2012)

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the collectors, especially for the hazardousness of the waste concerned.

The activities of collection, screening and sometimes pre-processing of WEEE, according to ABDI, are commonly developed by cooperatives, since the processes and pre-processing of collection of this waste can represent up to 15% of sales. In this refrain, due to the fact that other wastes are more widespread in the recycling process (such as plastic, aluminum and cardboard), it is estimated that in Brazil there are 600,000 employees in the cooperatives, and that every thousand tons of recycled material five new jobs appear in the recycling industry. It is in this area that the thought of cooperativism can be introduced in reverse logistics.

Cooperatives face problems that may result in their closure because of the exploitation of cheap labor and the non-adoption of a truly cooperative position, negatively reflected in the sector, weakening it and causing it to lose credibility (Ferreira et Dagnese, 2014). This problem has as an aggravation the lack of incentives on the part of the public power, especially in the municipal competence, making the work of the cooperatives even more precarious. Added to this is the lack of capacity building, promoting high turnover and reduced level of commitment, so that the sector makes clear the desire for greater support from the private sector, with partnerships and capacities (ABDI, 2013).

Even with the determination of the PNRS, the capital of Piauí does not have a specific policy for the disposal and collection of electronic waste and it is common for e-waste to be discarded as common waste and to go to the landfill.

While Teresina does not define guidelines for collecting and disposing of e-waste produced in the city, community institutions have found ways to reuse the discarded material and transform it into a generator of citizenship[1]

3. METHODOLOGY

This is an action research, since it favored the production and discussions regarding specific knowledge in the lived reality, under the perspective of the ennoblement of the hierarchical structures, which are responsible for fragmenting the quotidian (Molina, 2007). Regarding the context of the approach, it is qualitative and quantitative, being qualitative because it raised and analyzed non-numerical data (Silva et Menezes, 2005). The research is quantitative by focusing a number of small concepts, using structured and formal procedures for data collection, emphasizing objectivity and investigating numerical data through statistical procedures (Polit *et al.,* 2004).

It is characterized as exploratory, since it sought to provide greater familiarity with the subject under study, making it clear and allowing the formulation of hypotheses. Also, it is classified as a multisite study, since it evaluated some units, taking care to know the object of study in detail, being necessary to search, store and have access to the maximum of information and possible knowledge on the chosen subject, with an acceptable level of effort and expenditure of little time and resources (Martins, 2006).

The research was divided into three stages. In the first, a questionnaire with closed questions was applied to a sample of 60 people, in the morning and afternoon shifts, in all areas of the city, including 30 in the center of the city, 15 in the south, 5 in the north, 5 in the southeast, and 5 in the east. This questionnaire sought to understand how people behave in the face of the reverse logistics process of WEEE in the region.

In the second stage five WEEE collection points were located in the region, in addition to a specialized company responsible for receiving and processing. After a visit to one of the collection points, it was discovered that there are seven more points of recollection and a specialized company, totaling 12 points to be searched, identified by: E-Lixo Piauí; Connect Connection with the Future; Movement for Peace in the Periphery - MP3; Cuia.eco Project; Emaús Trapeiros; Projeto Clicar; Scrap A; Scrap B; Scrap C; Scrap D; Scrap E; Scrap F, and two companies present at the end of the WEEE reverse cycle chain, with locations in São Paulo, SP (Umicore Brasil) and Recife, PE (Lorene). The sampling type of this research was non-probabilistic and therefore non-random, providing an easier data collection process (Sweeney *et al.*, 2015).

After that, semi-structured interviews were carried out with the owners or managers of the waste collection points, asking about the company's performance in the region, its process, quantities collected, perspective for the future, vision of the current scenario, in order to respond to the objectives of this work. During the on-site observations, there were photographic registrations in some companies, with prior authorization, to enable a better understanding of how WEEE processing occurs in these institutions.

In the third step, semi-structured telephone and e-mail interviews were carried out with the companies specialized in the reverse logistics process of WEEE, located in São Paulo and Recife, in order to understand how the processing of these wastes occurs at the end of the reverse chain, which products are generated, the tailings, the ad-

1 http://www.portalodia.com/noticias/tecnologia/tecnologia-para-onde-vai-o-lixo-eletronico-92062.html

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vantages and disadvantages of this process, among other questions.

4. RESULTS AND DISCUSSION

Figure 2 presents a synthetic scheme of reverse logistics involving three members of the reverse chain of WEEE: consumer, supplier, and distributor.

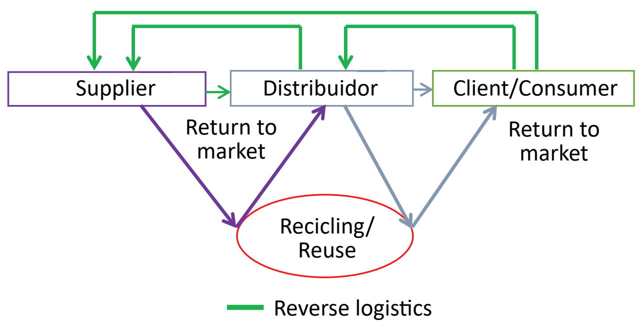

Figure 2. Simplified reverse logistics scheme for WEEE
Source: Author (2017)

Results of applied research with the population

The applied research carried out with the population was developed with the purpose of understanding the behavior and knowledge of citizens about the environmentally correct disposal of WEEE in the city of Teresina. The result is described in Table 1.

According to the data presented in Table 1, it is verified that 93% of the people know what electric and electronic garbage are, thus inferring that most of the interviewees can distinguish them from the common waste. Of these, however, when asked about the knowledge in terms of the risks related to the inappropriate disposal of WEEE, only 72% have knowledge about the subject.

Among those who know the risks, only 60% actually carry out the disposal of WEEE in an environmentally appropriate manner. On this point, Brazilian legislation is assertive about punitive measures. According to Law No. 12,305/2010, in case of improper disposal, the offender may be punished in the three different spheres, so that, in case of improper waste disposal, the law provides for a penalty that will be stipulated in accordance with the of Law no. 9.605 / 1998, Art. 54, which says:

> "Causing pollution of any nature at levels that result or may result in damage to human health, or that lead to the death of animals or the significant destruction of flora: (...) 2nd paragraph – If the crime: (...) V - Occurs by the discharge of solid, liquid or gaseous wastes, or debris, oils or oily substances, in disagreement with the requirements established in laws or regulations: Penalty - imprisonment, from one to five years" (Brasil, 1998).

Continually, it is noted that 72% of the population has some type of electronic device that is no longer useful or is not working in their possession, and that it will be discarded as soon as possible. Thus, it is observed that there is a significant amount of electro-electronic products to be discarded, so that it is even more necessary to develop the environmentally adequate collection and disposal activities of WEEE in order to avoid any socio-environmental damage.

According to Carvalho et al. (2016), the risk of contamination of the environment by the inappropriate disposal of WEEE is further aggravated by the lack of information from the people, so that it favors the lack of control in the management of these materials. The added risk of inadequate

Table 1. Result of the research done with the population of Teresina

Questions	Yes	No
1. Do you know what electric and electronic waste is?	93%	7%
2. Do you have any electronic equipment in your home (e.g. printer, monitor, mouse, keyboard, TV, DVD, mobile device, camera, hair dryer, etc.) that is no longer useful to you and discarded?	72%	28%
3. Do you know the risks of improper disposal of waste electrical and electronic equipment?	72%	28%
4. Do you know of any point of collection of electronic waste in Teresina?	30%	70%
5. Do you usually dispose of your home electronics when they are out of service or out of repair?	82%	18%
6. Do you think the place where you dispose of your used electronics is appropriate?	60%	40%

Source: Author (2017)

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disposal comes from the heavy metals that constitute the parts of an electronic device and are responsible for the deleterious effects of WEEE. The improper disposal or grounding and incineration, without previous treatment, may result in contamination of water, soil or air, due to the emission of substances that are harmful to the environment. Incineration, in particular, may result in the emission of mercury, lead and other toxic substances, in addition to the loss of material of high aggregate economic value, such as gold and silver, which can be recycled, as well as loss and increase of energy expenditure (Virgens, 2009).

Another important fact is that 70% of the people surveyed reported that they do not know of any suitable collection points for WEEE in the region of Teresina, PI. This fact is confirmed by the population's responses when asked about where to dispose of WEEE when necessary, as shown in Figure 3.

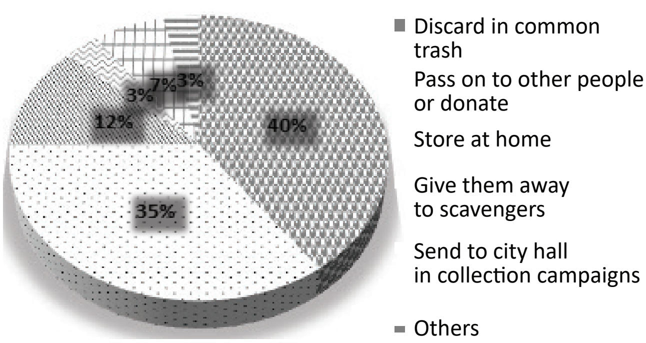

Figure 3. Destination of disposal of WEEE by the population
Source: Author (2017)

It can be seen from Figure 3 that 40% of people dispose of WEEE in common waste, 35% pass on to other people or donate, 12% store at home, 3% deliver to scavengers, 7% send it to the city hall when there is a collection campaign, and 3% give other destinations that were not mentioned. Considering only the percentage of interviewees who discard the waste in the common waste and those who store it at home, there is an accumulated 52% of the population that discards their waste in the wrong way. This is worrying, since more than half of WEEE are erroneously discarded, especially with the common waste, which is the largest representation among the forms of disposal mentioned. This contributes to the increase of the disposal of these wastes in landfills, consequently promoting several socioenvironmental damages, especially considering that 60% of the people interviewed believe that the place where they dispose is the correct one.

Siqueira et Marques (2012) consider that, in this scenario, the population is an essential part for the success of the adequate flow of waste, since citizens are the final consumers of the products and, consequently, those directly responsible for their correct disposal. However, these consumers may not always have enough information to properly dispose of them. In addition, the PNRS has not yet defined the role of each of the actors, a fact that further aggravates the lack of knowledge about the issue of waste disposal. The authors add that the unplanned dumping of these wastes contributes to aggravate the problem of the increasing scarcity of areas for the implantation of new landfills and compromises the capacity of regeneration of these resources in nature, since the proportion of common metals, such as copper, found in these waste is quite high: 1.0 ton of electronic waste contains up to 0.2 tons of copper. This metal could be reused by the industry, which would reduce its extraction from nature, since copper, when recycled, does not change its properties.

When the data are crossed between those who inappropriately dispose of the waste and those who consider it to be the correct destination for them, it is possible to observe that 65% of people know that their form of disposal is wrong. That is, most of those who discard it incorrectly acknowledge their error, which shows the need for more effective ways of raising awareness of the dangers arising from this practice.

The population of Teresina, for the most part, and according to the survey, is aware of the environmentally appropriate disposal of WEEE; however, because they do not know collection points of these materials, they end up doing the disposal in an inadequate way, which consequently promotes the contamination of the environment.

Results of applied research with collection points

Figure 4 shows the location of the WEEE collection points in Teresina.

Figure 4 presents the twelve points of WEEE collection in Teresina and shows that all the zones of the city are contemplated with at least one point of collection of the WEEE; nevertheless, it is emphasized that a greater quantity is concentrated in the southern zone of the city.

The WEEE collection activities in Teresina started in 2011 with the Projeto Clicar, aiming to offer something that would attract the attention of the young people in the community and reduce the inappropriate disposal of WEEE in the region. Then, other companies joined the initiative, becoming part of the select group that collects and disposes of the environmentally appropriate waste;

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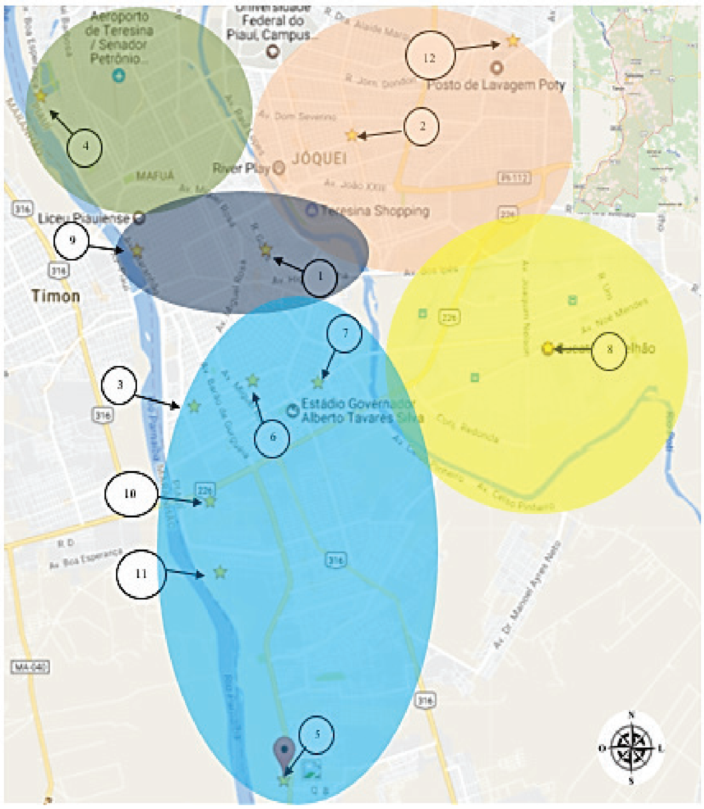

Subtitles				
City Zone				
N	S	SE	E	C
Collect point				
1	E-Lixo Piauí			
2	Connect Connection with the Future			
3	Movement for Peace in the Periphery-MP3			
4	Cuia.eco			
5	Projeto Clicar			
6	Scrap A			
7	Scrap B			
8	Scrap C			
9	Scrap D			
10	Scrap E			
11	Scrap F			
12	Emaús Trapeiros			

Figure 4. Location of collection points in Teresina
Source: Author (2017)

however, from 2013 onwards, there was a greater number of companies engaging in the execution of this activity, since, in this period, the company E-lixo Piauí began its activities in the capital, forming partnerships with several companies in the region.

In this sense, in order for the states to implement the selective collection system and treat the garbage generated, in 2010 the federal government implemented the PNRS, represented by Law No. 12,305/2010, establishing that by 2012 all states would be required to prepare an Integrated Management Plan, municipal, state and district, and that by 2014 all states would have to give the environmentally appropriate destination, with the effective selective collection and also extinguish the dumps and controlled landfills.

However, according to the magazine Cidade Verde (2016), the municipality of Teresina did not meet any of the deadlines. The state of Piauí does not have a specific policy for the treatment and correct destination of WEEE, forcing the capital to suffer the consequences promoted by the inappropriate disposal of electronic waste in the environment.

During the interviews, it was observed that some companies are already doing the process of collecting and disposing of environmentally adequate WEEE in the city, according to the owner of the company E-lixo Piauí. This activity is considered to be one of the most profitable in the middle of waste recycling, since the electronic waste has several components with added value, where the price per kilo of WEEE in the recycling market is not higher than that of copper, which makes the collection process even more attractive to companies.

In this sense, most companies receive all types of waste electrical and electronic, with the exception of companies Connect Connection with the Future, Project Cuia.eco and Scrap D, which receive only medium and small waste, because these establishments do not have space sufficient to adequately store large WEEE. Thus, it can be observed that in the city of Teresina, any type of WEEE can be disposed of in an environmentally appropriate manner.

According to the United Nations (UN, 2015), Brazil is the second largest producer of WEEE in Latin America, with 1.4 million tons produced annually. Of this total, according to the Brazilian Association of Companies and

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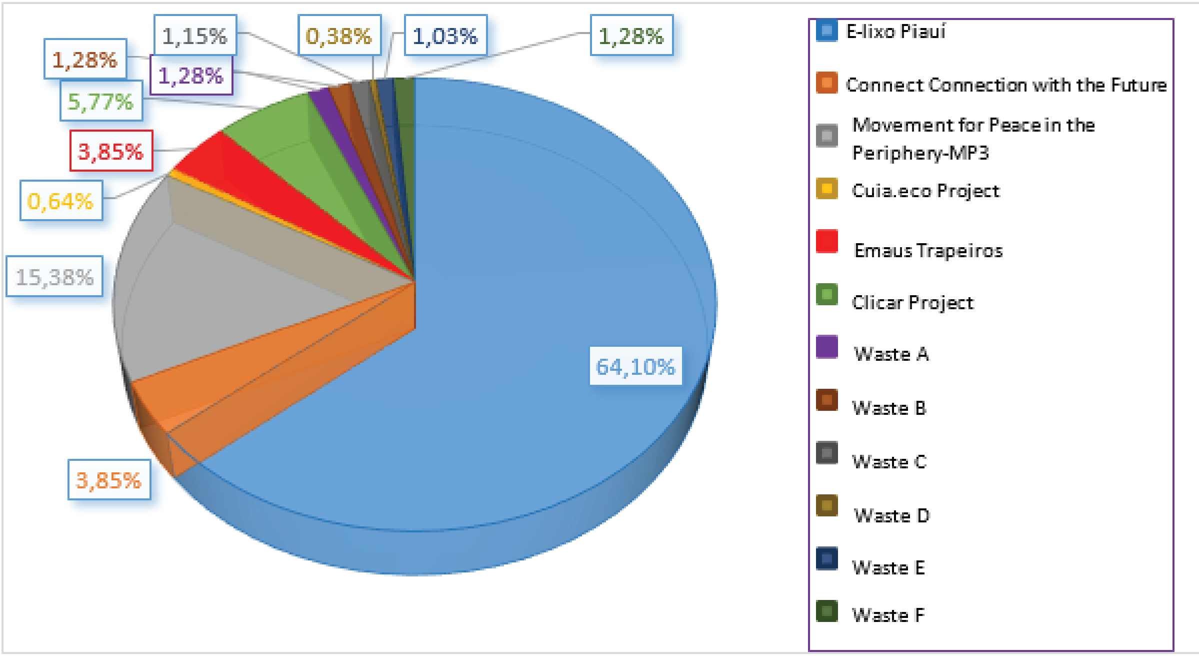

Figure 5. Representation that each company occupies in relation to the total WEEE collected in Teresina, Piauí.
Source: Author (2017).

Treatment of Waste and Effluents (ABETRE, 2016, acronym in Portuguese), the state of Piauí occupied the 22nd position in the national ranking of the most generators states of electronic waste in Brazil in 2015, producing about 9,8 thousand tons per year.

However, it should be noted that the amount of electro-electronic waste collected by the investigated companies reaches a cumulative of 7,900 kg/month, which represents only 11.61% of the total WEEE generated in Piauí, showing that even with initiatives of some companies in collecting such waste, the state is still far from providing an environmentally appropriate destination for the generated electrical and electronic waste. From this total, it is possible to observe the representation that each company occupies in the collection of WEEE in Teresina, as shown in Figure 5.

It is observed, according to Figure 5, that a large part of the WEEE collected in the city is made by the company E-lixo Piauí, with a total of 64.10%, followed by the MP3 Company with 15.38% and Projeto Clicar with 5.77%; the other companies collected less than 4% each of the total.

According to Brum et al. (2011), the environmental problems opened a discussion about the changes to be adopted to minimize the environmental degradation, since the main resource to transform the society before the reverse logistics of the WEEE is the education on the selective collection, trying to show the importance of sustainable development.

All the companies analyzed report that there are no risks involved in the execution of this activity. On this basis, in 2013, ABNT NBR 16.156 (2013) defined, at the national level, the requirements for carrying out the reverse logistics activity of WEEE, in order to ensure the practice of this activity in an environmentally adequate manner, in order to minimize the risks of contamination of the environment and workers. The standard considers that these residues cannot be stored in the open or in direct contact with the soil, because the climatic changes can lead to the process of oxidation of the metals present in the WEEE, promoting the contamination of the soil and, consequently, the contamination of the water table, because of the formation of soluble toxic substances. In addition, this situation can also lead to the formation of environments that are conducive to the proliferation of endemic vectors, such as *Aedes Aegypti* (ABNT, 2013).

In this sense, according to Ferreira et Wermelinger (2013), the main factor to be given special attention to WEEE is the fact that in its composition these residues contain heavy metals, which can lead to several diseases arising from the interaction of man with the WEEE, and may be aggravated if it occurs by ingestion, inhalation or dermal contact.

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Figures 6 and 7 show how WEEEs are stored by some companies.

Figure 6. WEEE storage
Source: Author (2017)

Figure 7. WEEE storage
Source: Author (2017)

Figure 6 shows that the storage of WEEE is in disagreement with NBR 16.156: 2013, since the storage is being made in the open and in contact with the soil, being able to undergo climatic storms, which cause the oxidation of the metals present in the WEEE, and, consequently, to promote environmental contamination, also serving as a focus for the proliferation of endemics vectors.

Figure 7 shows that WEEE storage is being adequately done by some companies, since it is in a closed environment and does not have direct contact with the soil, which avoids contamination of the environment and the proliferation of endemic vectors.

Kilic et al. (2015) report that the reverse logistics of WEEE is the most sustainable form that contributes directly to the preservation of natural resources. Therefore, reverse logistics provides gains such as reduction in the consumption of natural resources for the use of raw materials, the intelligent reuse of resources, strengthens the environmental responsibility of all, encourages the use of clean technologies, and prevents pollution and contamination of the environment.

However, according to business owners, the implementation of reverse logistics of WEEE in the city of Teresina is a complex task, since several difficulties are encountered, among which:

- The difficult access of WEEE collection directly in the residences, since the people of the city are not yet accustomed to this activity, and end up making the process difficult;
- The lack of participation and interest on the part of the government to support this initiative, and thus to play a strategic role in sustainable development.

Still, according to the owners, the lack of incentive by the state government for this activity contributes to people having the behavior of not carrying out the environmentally appropriate disposal of WEEE from their possession, as it does not create a general awareness as advised. Thus, according to Law 12,305/2010, Section 2, entitled “Shared Responsibility”, it has been stated that it is the responsibility of all (consumers, public authorities, manufacturers, importers, distributors, traders, scavengers, and recyclers) the final destination of waste generated in an environmentally appropriate way.

In this sense, some companies are investing in ways to publicize these activities to attract the public that does not yet have the knowledge in terms of where the collection points of WEEE are located in the region. It was detailed that the divulgation is carried through Website, social networks, lectures, radios, and pamphlets.

The company responsible for transporting the WEEE collected in Teresina is E-Lixo Piauí, which receives the waste from most of the companies mentioned in this work; thus, it is responsible for transporting this material to the company LORENE, located in the city of Recife, PE.

Results of the applied research with the companies at the end of the reverse cycle of WEEE

In order to know how the Teresina WEEE is processed, the companies that receive and manufacture this type of waste are contacted.

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LORENE

LORENE is considered to be one of the first to carry out the process of environmentally correct disposal of wastes such as catalysts, electro-electronic and others containing precious metals. All material acquired by the company is destined for recycling, generating financial and sustainable results for all partners (assemblers, service providers, mining companies, waste managers among others), which makes feasible the logistics and reverse manufacturing activity of the company (LORENE, 2017).

The company has a logistics system that allows it to buy waste from electronic waste throughout the country and in several countries around the world, developing the work of giving environmentally correct destination to WEEE.

In Brazil, the company acts by collecting the WEEE, which are then sent to the USA, where they go through manufacturing processes and thus return to the initial production cycle. However, in order for this material to be exported, it is necessary to go through the steps shown in Figure 7.

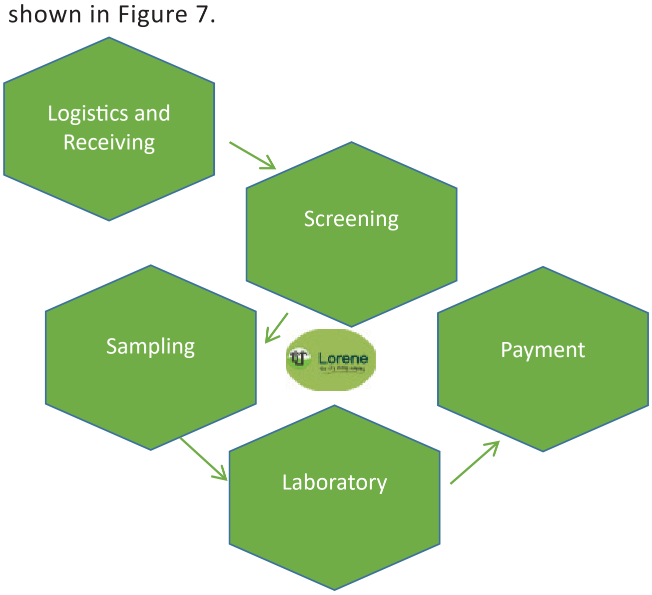

Figure 7. Stages through which WEEE goes through in LORENE located in Brazil
Source: Lorene (2017)

- **Logistics and reception (collection) –** The company has a fleet of more than 150 vehicles to carry out the collection of waste throughout the national territory, so that this collection can be made directly to the employee who delivers in the company. All material received is duly identified, so that the company can ensure traceability throughout the process;

- **Screening** - In this step, the materials are separated and sorted based on catalogs, which are constantly updated and validated by the laboratory, ensuring the safe negotiation of waste;

- **Sampling** - Sampling consists of batch processing through an automated homogeneous and representative sample collection system so that each type of material can be routed to specific production lines (catalysts, electronics, and miscellaneous materials). This automated system is composed of a set of crushers, mills and sample dividers, and the generated samples are submitted to spraying, melting and sifting processes, depending on the specifications of each material. This process guarantees a sample that will be used to evaluate the quantity of precious metals contained in each batch of electronic scrap;

- **Laboratory** - The laboratory is responsible for the chemical analysis of all wastes collected by the company;

- **Payment** - Soon after the screening and chemical analysis of the materials, the company makes the payment to the employee responsible for the waste. Then a report is generated to guarantee the content of the metals present in the lot, to be directed to the commercial department (LORENE, 2017).

UMICORE BRASIL

Umicore is an international materials technology company with headquarters in Brussels and Belgium. Throughout its 100 years of existence, Umicore has consolidated and developed international operations, operating in all continents, being present in 36 countries. One of these countries is Brazil, based in Guarulhos, SP, Americana, SP, and Manaus, AM, with approximately 660 employees, manufacturing and offering various products, and working in the refining and recycling of metals. It specializes in the processing of complex materials composed of precious metals, including printed circuit boards (PCBs), processors, memories, among others which form part of WEEE (UMICORE, 2016).

The company rarely collects the materials because there are suppliers spread all over the country who do this service to the local industries and prefectures and then pass it on to the company. The fact that it is at the end of the reverse cycle chain makes the company depend on the services made by the suppliers to begin the process of reverse logistics of the materials. The ap-

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proved companies offer logistics and manufacturing services to their regional customers to collect, separate and transport, recycling more than 17 types of metals, and the inert slag generated in the process is used as an aggregate for concrete.

In Brazil, the stages of sampling and analysis of the materials, characterization of the batches, identification of the chemical composition of the materials and realization of their purchases, taking around 65 days, are carried out. The company then organizes the exportation of the lots to Umicore Belgium to carry out the final stage of refining the waste.

Currently, the company processes 350 thousand tons of materials annually. As an example, the processing steps of mobile handsets and printed circuit boards are described below:

1. They are received at the Umicore plant;
2. The materials undergo a process of grinding and homogenization;
3. From the resulting material samples are taken to determine the chemical composition of the batch;
4. The materials are sent to a high temperature furnace where the organic slurry is burned and the metals are concentrated in a liquid phase;
5. After being removed from the furnace, the metals concentrated in ingots follow for separation and refining.
6. Metal-free slag goes to road paving.

According to the process described above, it is possible to observe that the company carries out the process of environmentally adequate destination of the materials received, which, after being processed, are destined for the production of new products or, even, for the production of the same line, closing the reverse logistics process of WEEE.

5. FINAL CONSIDERATIONS

The research carried out with the population indicates that it is aware of the environmentally adequate destination of WEEE, although most do not dispose of it properly because they do not know of any disposal points for this type of waste.

In the course of this research, 12 collection points were located in the studied region, distributed throughout all zones, showing that the city of Teresina has a considerable number of collection points. However, due to the lack of publicity, both by public and private agencies, these points end up being anonymous, making it difficult to dispose of WEEE as environmentally friendly.

In this sense, it can be said that the city of Teresina already includes, among the activities of reverse logistics, the collection of WEEE; however, it is necessary to develop a better dissemination policy in the region, and the interest on the part of the State Government in encouraging and assisting in this activity so that the population is properly oriented about where the collection points are located.

In relation to companies that collect WEEE in Teresina, they perform a very important work for society and the environment, but face difficulties in the amount of waste from electronic waste, since the great majority of the population does not yet have the knowledge that there are already companies in the city specialized in the collection and environmentally correct disposal of WEEE.

As for the companies specialized in the manufacture of WEEE, it was possible to know how the activities of these companies are developed, and it is verified that all the post-consumer waste collected in the city of Teresina by the companies mentioned is sent to a company, located in Recife, that is responsible for making the manufacturing process of these wastes, making it possible to return the materials to the initial production cycle.

It is concluded, therefore, that Teresina, PI, is advancing in the management of WEEE, but it still needs to be publicized and participated by companies and public agencies so that the population becomes aware and takes responsibility for the process of environmentally adequate disposal of these wastes.

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